

# **S P E C I F I C A T I O N**

Docket No. **SILA0005**

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, **Donald A. Kerth**, a citizen of the United States of America, residing in the State of Texas, have invented new and useful improvements in a

## **METHOD AND APPARATUS FOR ENHANCING SIGNAL QUALITY WITHIN A WIRELESS RECEIVER**

of which the following is a specification:

## BACKGROUND OF THE INVENTION

### 1. Technical Field

The present invention relates to wireless transceivers in general, and in particular to radio frequency transceivers. Still more particularly, the present invention relates to a method and apparatus for enhancing signal quality within a radio frequency receiver.

### 2. Description of Related Art

Unlike wireline communication environments, a wireless communication environment has to accommodate a large number of users sharing different parts of the frequency spectrum with very strong signals coexist adjacent to very weak signals. Hence, a wireless receiver should be able to select the signal of interest while rejecting all other signals. According to their respective architecture, wireless receivers can generally be classified under two categories, namely, homodyne receivers and heterodyne receivers.

With a homodyne receiver, the desired signal is initially selected by a bandselect filter and is subsequently amplified by a low-noise amplifier. The desired signal is then frequency translated by a mixer to DC before other baseband operations are performed on the desired signal. With a heterodyne receiver, the desired signal is sent through receiver components similar to those in the homodyne receiver with the exception that the desired signal is translated to an intermediate frequency (IF) when signal processing operations are performed.

For heterodyne wireless receivers, image rejection refers to the ability to select the desired signal from the image of the desired signal spaced away by twice the IF signal. Basically, a heterodyne wireless receiver should be able to select the desired signal

1 from its image. Otherwise, the subsequent detector circuit within the heterodyne wireless  
2 receiver will not be able to distinguish between the desired signal and the image signal, and  
3 the output becomes the superposition of both signals. Accordingly, image rejection is one  
4 of the various functions that heterodyne wireless receivers need to provide.

5  
6 The present disclosure provides a method and apparatus for alleviating the  
7 image problem in signals within a wireless receiver such that the quality of the signals  
8 within the wireless receiver can be enhanced.

## SUMMARY OF THE INVENTION

In accordance with a preferred embodiment of the present invention, an image of a desired signal is down-converted to a baseband signal by a digital down converter. The energy of the baseband signal is then determined. If the energy of the baseband signal is equal to or greater than a predetermined threshold, then the IF is swapped for any incoming signals. If the energy of the baseband signal is less than the predetermined threshold, then the IF is maintained for any incoming signals.

All features and advantages of the present invention will become apparent in the following detailed written description.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention itself, as well as a preferred mode of use, further objects, and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a block diagram of a wireless receiver, in accordance with a preferred embodiment of the present invention;

Figure 2 is a high-level logic flow diagram of a method for enhancing signal quality within the wireless receiver from Figure 1, in accordance with a preferred embodiment of the present invention;

Figure 3 is a block diagram of a wireless receiver for implementing the method of Figure 2, in accordance with an alternative embodiment of the present invention; and

Figures 4a-4b graphically illustrate the potential improvement in the interference performance in accordance with a preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawings and in particular to Figure 1, there is depicted a block diagram of a wireless receiver, in accordance with a preferred embodiment of the present invention. As shown, an RF receiver 10 includes an antenna 11, a low-noise amplifier 12, a pair of RF mixers 13a-13b, an IF filter 15, an analog-to-digital converter (ADC) 16 and a digital down converter 18 along with additional receiver circuitry (not shown) that are well-known to those skilled in the art. In addition, RF receiver 10 includes a radio frequency local oscillator (RFLO) 14 coupled to RF mixers 13a-13b for generating an in-phase signal and a quadrature signal. RF receiver 10 also includes an LO frequency control module 19 coupled to RFLO 14 for controlling the oscillation frequency of RFLO 14. Similarly, a down conversion controller 92 is coupled to a digital complex sinusoid signal IFLO 17 for controlling the oscillation frequency of IFLO 17 that is connected to digital down converter 18. An energy detector 91 is coupled to the output of digital down converter 18 to receive down-converted signals from digital down converter 18. Based on the information from the received down-converted signals, energy detector 91 can selectively adjust the operation of RFLO 14 and IFLO 17 via LO frequency control module 19 and down conversion controller 92, respectively.

RF signals are initially received by antenna 11. After passing through low-noise amplifier 12, the RF signals enter an in-phase path 2 and a quadrature path 3 via a junction 4. A first input of RF mixer 13a is connected to in-phase path 2, and a second input of RF mixer 13a is connected to an in-phase output of RFLO 14. The output of RF mixer 13a provides in-phase IF signals to IF filter 15 via an in-phase signal path I. Similarly, a first input of RF mixer 13b is connected to quadrature path 3, and a second input of RF mixer 13b is connected to a 90° out-of-phase output of RFLO 14. The output of RF mixer 13b provides quadrature IF signals to IF filter 15 via a quadrature signal path Q. Both IF signal paths for RF receiver 10 are approximately 200 kHz.

1 In the embodiment shown in Figure 1, the IF signals within in-phase signal  
2 path I and quadrature signal path Q of RF receiver 10 are completely independent from  
3 each other until the final down conversion to a baseband signal. In other words, each of  
4 the IF signal paths I and Q does not have a complex transfer function. Because the transfer  
5 functions for the IF signal paths I and Q are real, an RF signal can be down-converted to  
6 a +200 kHz IF signal or a -200kHz IF signal by changing the oscillation frequency of  
7 RFLO 14.

8  
9 With reference now to Figure 2, there is depicted a high-level logic flow  
10 diagram of a method for enhancing signal quality within a wireless receiver, such as  
11 wireless receiver 10 from Figure 1, in accordance with a preferred embodiment of the  
12 present invention. When the wireless receiver is being powered up or undergoing a channel  
13 change, as shown in block 21, an image of a desired signal is down-converted to a  
14 baseband signal, as depicted in block 22. The down-conversion of an image to a baseband  
15 signal is performed via two stages. The first stage is to utilize LO frequency control  
16 module 19 (from Figure 1) to change the oscillation frequency of RFLO 14 (from Figure  
17 1) as follows:

$$f_{\text{RFLO}} = f_{\text{CH}} - f_{\text{IF}}$$

21 where  $f_{\text{RFLO}}$  = oscillation frequency of RFLO 14

22  $f_{\text{CH}}$  = frequency of channel

23  $f_{\text{IF}}$  = frequency of IF signal

24  
25 The second stage is to adjust the digital complex sine wave used within digital down  
26 converter 18 (from Figure 1) by changing the frequency of IFLO 17 (from Figure 1) via  
27 down conversion controller 92 (from Figure 1). Specifically, the adjustment is performed  
28 as follows:  
29

$$IFLO(t) = e^{+j\omega_{IF}t}$$

$$\text{where } e^{+j\omega_{IF}t} = \cos\omega_{IF}t + j\sin\omega_{IF}t$$

$$\omega_{IF} = 2\pi f_{IF}$$

No modification to the IF signal paths I and Q within RF receiver 10 in Figure 1 is required.

Next, the energy of the down-converted image signal is measured, as shown in block 23. For receiver 10 in Figure 1, the image energy measurement can be performed by energy detector 91 that is coupled to the output of digital down converter 18. A determination is then made as to whether or not the energy of the down-converted image signal is equal to or greater than a predetermined threshold, as depicted in block 24. For the present embodiment, the predetermined threshold is approximately -71 dBm. If the energy of the down-converted image signal is equal to or greater than the predetermined threshold, the IF is swapped, as shown in block 25. For receiver 10 in Figure 1, IF swapping includes changing the local oscillation frequency of RFLO 14 via frequency control module 19, as follows:

$$f_{RFLO} = f_{CH} + f_{IF}$$

where  $f_{RFLO}$  = oscillation frequency of RFLO 14

$f_{CH}$  = frequency of channel

$f_{IF}$  = frequency of IF signal

In addition, IF swapping also includes maintaining the oscillating frequency of IFLO 17 (from Figure 1) via down converter controller 92 (from Figure 1), as follows:



$$IFLO(t) = e^{+j\omega_{IF}t}$$

$$\text{where } e^{+j\omega_{IF}t} = \cos\omega_{IF}t + j\sin\omega_{IF}t$$

$$\omega_{IF} = 2\pi f_{IF}$$

Otherwise, if the energy of the down-converted image signal is less than the predetermined threshold, the IF is maintained, as depicted in block 26. For receiver 10 in Figure 1, maintaining IF includes maintaining the local oscillation frequency of RFLO 14 via frequency control module 19, as follows:

$$f_{RFLO} = f_{CH} - f_{IF}$$

where  $f_{RFLO}$  = oscillation frequency of RFLO 14

$f_{CH}$  = frequency of channel

$f_{IF}$  = frequency of IF signal

In addition, maintaining IF also includes changing the oscillating frequency of IFLO 17 (from Figure 1) via down converter controller 92 (from Figure 1), as follows:

$$IFLO(t) = e^{-j\omega_{IF}t}$$

$$\text{where } e^{-j\omega_{IF}t} = \cos\omega_{IF}t - j\sin\omega_{IF}t$$

$$\omega_{IF} = 2\pi f_{IF}$$

Subsequently, normal signal processing is resumed, as shown in block 27.

For performing the second stage of the image signal down-conversion, instead of adjusting the digital complex sine wave used within digital down converter 18

1 in Figure 1, a switch can be utilized to swap the two IF signal paths (from +200 kHz to  
2 -200 kHz). An implementation of a switch is further illustrated in details in Figure 3.

3  
4 Referring now to Figure 3, there is depicted a block diagram of a wireless  
5 receiver for implementing the method of Figure 2, in accordance with an alternative  
6 embodiment of the present invention. As shown, an RF receiver 30 includes an antenna  
7 31, a low-noise amplifier 32, a pair of RF mixers 33a-33b, an IF filter 35, an ADC 36, a  
8 switch 37 and a digital down converter 38 along with additional receiver circuitry (not  
9 shown) that are well-known to those skilled in the art. In addition, RF receiver 30 includes  
10 a RFLO 34 coupled to RF mixers 33a-33b. RF receiver 30 also includes an LO frequency  
11 control module 39 coupled to RFLO 34 for controlling the oscillation frequency of RFLO  
12 34. An energy detector 93 is coupled to the output of digital down converter 38 for  
13 measuring the energy the down-converted image signal (*i.e.*, block 23 of Figure 2). Based  
14 on the energy information from the received down-converted image signal, energy detector  
15 91 can selectively adjust the node connections within switch 37 and the oscillation  
16 frequency of RFLO 34 via frequency control module 93.

17  
18 The basic functional components of RF receiver 30 are similar to those of  
19 RF receiver 10 from Figure 1. The main difference between RF receiver 30 and RF  
20 receiver 10 from Figure 1 is that instead of using an IFLO and a down conversion  
21 controller to adjust the digital complex sine wave used in a digital down converter, a  
22 switch, such as switch 37, is used to swap the IF signal paths I and Q. Nodes a and b of  
23 switch 37 are connected to the IF signal path I, and nodes c and d of switch 37 are  
24 connected to the IF signal path Q. The above-mentioned down-conversion of an image to  
25 a baseband signal (*i.e.*, block 22 in Figure 2) can be performed by changing the initial  
26 connections of node a-to-node b and node c-to-node d to subsequent connections of node  
27 a-to-node d and node c-to-node b, respectively. Although switch 37 is shown to be located  
28 between ADC 36 and digital down converter 38 in Figure 3, switch 37 can be located

anywhere within the IF signal paths. For example, switch 37 can be located between IF filter 35 and ADC 36 or between RF mixers 33a-33b and IF filter 35.

For RF receiver 30, the IF swapping (*i.e.*, block 25 in Figure 2) includes the changing of the local oscillation frequency of RFLO 34 via frequency control module 93 as  $f_{\text{RFLO}} = f_{\text{CH}} + f_{\text{IF}}$ , along with maintaining the node connections in switch 37 as node a-to-node d and node c-to-node b. On the other hand, the maintaining IF (*i.e.*, block 26 in Figure 2) for receiver 30 includes maintaining the local oscillation frequency of RFLO 34 via frequency control module 93 as  $f_{\text{RFLO}} = f_{\text{CH}} - f_{\text{IF}}$ , along with changing the node connections in switch 37 as node a-to-node b and node c-to-node d.

With reference now to Figures 4a-4b, there are illustrated the potential improvement in the interference performance in accordance with a preferred embodiment of the present invention. In Figure 4a, because of the limited image rejection on a -400 kHz interferer 41, -400 kHz interferer 41 images into the +200 kHz side as an interference signal 42, and as a result, interference signal 42 interferes with a desired signal 43. Figure 4b shows the spectrum of a swapped IF according to the present invention. As shown in Figure 4b, -400 kHz interferer 41 is located at 600 kHz and a desired signal 44 is located at -200 kHz. Thus, -400 kHz interferer 41 is no longer an image of desired signal 43.

As has been described, the present invention provides a method and apparatus for enhancing signal quality within a wireless receiver. Although the down-conversion is shown as  $f_{\text{RFLO}} = f_{\text{CH}} - f_{\text{IF}}$ , it is understood by those skilled in the art that down-conversion can be performed as  $f_{\text{RFLO}} = f_{\text{CH}} + f_{\text{IF}}$  and the image energy will be measured at +IF correspondingly.

The method and apparatus of the present invention are applicable to RF receivers suitable to be used in TDMA communication networks, such as Global System for Mobile communications (GSM) networks. Although an RF receiver is used to illustrate

1 the present invention, it is understood by those skilled in the art that the present invention  
2 is also applicable to the receiver portion of wireless transceivers.

3  
4 While the invention has been particularly shown and described with reference  
5 to a preferred embodiment, it will be understood by those skilled in the art that various  
6 changes in form and detail may be made therein without departing from the spirit and scope  
7 of the invention.